

Surface Geology of South-west Pennsylvania and adjacent portions of West Virginia and Maryland. By John J. Stevenson, Professor of Geology in the University of the City of New York.

(Read before the American Philosophical Society, August 15, 1879.)

INTRODUCTION.

I. *Benches along Cheat River and vicinity—Along the Monongahela River—George's Creek—Redstone Creek—Along the National Road—Chestnut Ridge—Youghiogheny River—Westmoreland County, west from Chestnut Ridge—Ligonier Valley—Somerset County—East from the Alleghanies.*

II. *Resumé of the Facts—The Horizontal Benches—The River Terraces—Conclusions.*

The region in which the observations recorded in this paper were made, embraces of Pennsylvania the counties of Fayette, Westmoreland, Washington and Greene, with parts of Alleghany, Beaver and Somerset; of West Virginia, parts of Monongalia, Preston, Mineral and Hardy; and of Maryland, the extreme western portion. But the observations were made chiefly in the four counties of Pennsylvania first named and in Monongalia county of West Virginia.

The Alleghany Mountains of Pennsylvania form the eastern boundary of Somerset county. West from these in the same county are Negro Mountain and the Viaduct Axis, which unite with the Alleghanies near the northern line of Maryland to form Prof. W. B. Rogers' Tygart's Valley anticlinal in West Virginia. This great anticlinal is divided by Tygart's Valley into two monoclinal ridges, known as Cheat Mountain and Rich Mountain.

Laurel Ridge, the next west from Negro Mountain in Pennsylvania, is a bold mountain separating Westmoreland and Fayette counties from Cambria and Somerset; it extends into West Virginia and dies out before reaching the Great Kanawha river. Chestnut Ridge passes through Westmoreland and Fayette counties at twelve or fifteen miles further west, and is separated from Laurel Ridge by the Ligonier Valley, a canoe-shaped synclinal, which disappears southward not far beyond the southern line of Pennsylvania. Chestnut Ridge becomes insignificant soon after entering West Virginia, but in Pennsylvania it is almost as imposing as Laurel Ridge or the Alleghanies. West from Chestnut Ridge, only the Saltsburg anticlinal is strong enough to affect the topography. It forms Brush Ridge in Westmoreland and Fayette counties, but disappears very near the line of West Virginia.

The drainage west from the Alleghanies belongs to the Ohio river system and the smaller streams are tributary to the Conemaugh, the Youghiogheny, the Cheat, or the Monongahela. The first of these large streams flows into the Alleghany, while the second and third are tributaries to the Monongahela, which unites with the Alleghany at Pittsburgh to form the Ohio.

The Alleghanies of Virginia are reached in Maryland. They are not the same with those of Pennsylvania, but belong to the series of anticlinals next east. In this region, the Potomac river, rising near the Alleghanies of Pennsylvania, breaks through the Alleghanies of Virginia and flows past Cumberland on its way to the Atlantic Ocean.

Within the whole area examined, no traces of glacial drift occur, except along the banks of the Ohio river, where such material appears on the terraces, having been brought down by the Beaver and Alleghany rivers from the northern counties.

Some notes respecting the river terraces of the Ohio and Monongahela rivers were given in my report on the Greene and Washington district of Pennsylvania (1875). The observations begun in 1875 were continued during 1876 and 1877, and the surface geology was studied as closely as was possible without interfering with the economic investigations, which were the main object of the survey. Some of the observations are recorded in my report on the Ligonier Valley of Fayette and Westmoreland counties (1877). Barometric measurements were made wherever a terrace or bench could be recognized, but, in very many cases, these observations proved to be worthless as no spirit-leveled line was within reach to be used as a base. The measurements given in this paper were verified by direct reference to leveled lines and by repetitions.

I.

BENCHES ALONG CHEAT RIVER AND ITS VICINITY.

Cheat and Monongahela rivers unite in Pennsylvania at about two miles north from the line of West Virginia. Their channel-ways diverge rapidly, so that the former stream issues from Chestnut ridge at little more than three or four miles south from the State line, while the latter breaks through the same ridge at fully thirty miles further south. The course of Cheat is rudely north-west, and that of the Monongahela rudely north and south.

Stewartstown Benches. In the peninsula between these rivers and west from Chestnut Ridge, a line of high knobs begins at about a mile west of south from the mouth of Cheat and continues in an irregularly south direction to Dorsey's knob beyond Morgantown in West Virginia. These hills are nearly alike in height and reach to about 600 feet above the rivers at their junction. They are rudely conical and their sides are terraced. On one of these hills is the village of Stewartstown, at nearly three miles from Cheat river. In descending from this place to either river, the following series of benches was seen :

Tenth Bench.....	525 ft. above river,	1295 ft. above tide.
Ninth "	465 " "	1235 " "
Eighth "	425 " "	1195 " "
Seventh "	360 " "	1130 " "
Sixth "	330 " "	1100 " "
Fifth "	280 " "	1050 " "
Fourth "	210 " "	980 " "
Third "	180 " "	950 " "
Second "	80 " "	850 " "
First "	20 " "	790 " "

Ice's Ferry. Descending from the State line to Ice's ferry, on Cheat river, at nearly nine miles above its mouth, one sees the first, second, third, sixth, seventh and eighth benches of the series just given, but the fourth and fifth have been so disguised by erosion that they cannot be recognized. Above the third, there are no transported fragments, and the higher benches to the sixth are covered by an irregular deposit of sand with more or less clay. But no clay was observed on the eighth bench. Ascending the opposite side of the river and following the road toward Morgantown, one finds rolled and polished stones, mostly of small size, occurring in great numbers up to the level of the third bench, where they suddenly disappear. The ninth bench is reached on this road at about three miles from the river near the church and school house. The mile-ground, a level stretch about a mile long and nearly the same distance from Morgantown, is on the eighth bench.

Standing here and casting the glass around the horizon, one finds this bench marked by flat-topped hills far beyond Decker's creek, which enters the Monongahela at Morgantown, while the same bench is distinctly continuous along the face of Chestnut Ridge southward to certainly beyond the gorge of Booth's creek, which enters the Monongahela river at somewhat more than 12 miles south from the State line. As ascertained from the records of wells bored or dugged on the mile-ground, the deposit consists of coarse sand, sometimes containing a little blue clay, in all from 4 to 22 feet thick.

The seventh bench of the Stewartstown series is reached further along the road, where the valley of Decker's creek is first reached, and it is continuous thence around the hills to the Monongahela side. The third bench is well marked at Morgantown and, opposite that village, decayed shells of *unio* have been ploughed up at that level.

Line Ferry. Here, at three miles from the mouth of the river, the seventh, eighth and ninth benches of the Stewartstown series are distinct on the West Virginia side, but the lower ones have been removed or they have been disguised by erosion so as to be unrecognizable.

In descending from the north towards this ferry, one has difficulty in recognizing any of the benches, as the hill is abrupt and covered with forest; but rolled stones appear suddenly and in great numbers at 210 feet above the river bed, and increase thence in size as well as in number to the surface of the stream; while on the opposite side, transported fragments are numerous up to the level of the fifth bench. On both sides the higher benches are covered with sand, showing no polished fragments, but containing many small pieces of rock belonging to the immediate vicinity, which have been little affected by weathering and evidently have not been subjected to the action of running water.

BENCHES ALONG THE MONONGAHELA RIVER.

Between the State Line and George's Creek. Coming from the south to Point Marion, where the Cheat and Monongahela rivers unite, one finds all the Stewartstown benches distinct except the third, which has been de-

stroyed by erosion on the east side of the Monongahela, though it is still shown on the west side. The higher benches are almost equally distinct on both sides of the river. Polished fragments occur in great numbers up to the line of the fourth bench and, even at that elevation, many of them are of enormous size.

Crossing the Ferry at Point Marion and taking the hill-road to New Geneva, at the mouth of George's creek, one reaches the third bench at half a mile from the river. It is covered by coarse sand mingled with clay, which has boulders freely distributed throughout its whole mass. Such fragments are numerous up to 280 feet from the water's edge, the line of the fifth bench. The eighth bench is reached at somewhat more than a mile from Cheat river, and at the first cross-road it bears a deposit of sand whose thickness has not been determined. A flat-topped hill near this place marks the level of the ninth bench.

The fifth bench is of interest here. It is reached on this road very soon beyond the divide separating George's creek from Cheat river. There it bears a valuable fire clay with pockets of excellent glass sand. The irregularity of the deposit is shown by sections obtained in two neighboring pits. The one shows :

1. Sand, clay, etc.....	11 feet.
2. Sand, white, very clean.....	3 "
3. Clay, ferruginous, sandy.....	1 foot.
4. Clay, black, very good	1 "
5. Clay, white, good, but containing ferruginous streaks	7 feet.
6. Clay, ferruginous, seen.....	10 "
Total.....	33 feet.

The other section is :

1. Sand, clay, etc.....	8 to 10 feet.
2. Clay.....	3 to 10 "
3. Ferruginous conglomerate.....	0 ft. 1 inch.
4. Glass sand.....	6 feet.
5. Sand, inferior.....	unknown.

Respecting the thickness of the ferruginous clay, No. 6 of the first section, nothing is known further than that at 10 feet from the top the tools used in boring became hopelessly fast. An attempt was made to bore through the sand, No. 5, of the second section, but the tools could not be pushed beyond 15 feet.

At a little distance beyond the pits, the third bench of the Stewartstown series is reached, but the fourth bench has been masked by erosion so that the wash from the thick deposit on the fifth covers the place of the fourth and becomes continuous with the deposit on the third. Throughout the deposits on both benches, transported fragments are found in vast numbers. A well digged on the third bench is 23 feet deep and does not reach the bottom of the sandy deposit. At a little way beyond, the bottom of the sand is reached and the thickness to the rocky shelf is shown to be 35 feet.

The black clay of the first section, commonly known as the "swamp clay," was reached in a boring here at 25 feet from the surface. In it, amid the numerous fragments of half-rotted wood, the cupule of an acorn was found along with what seemed to be berries of the black haw. The latter were thoroughly carbonized and crumbled rapidly on drying; but the acorn cup was still tough, and it was kept for some time as a curiosity. The wood in this clay is tough enough to snap in breaking and it has the peculiar tint characterizing the half-rotted wood so frequently seen in peat bogs.

A point of the third bench projects towards George's creek at a little north from the road. *Unio* shells, much decayed, are common here and are barely covered by the soil.

A rise in the road at half a mile nearer to New Geneva brings it again to the level of the fifth bench. There a small deposit of glass-sand was found, but it was soon worked out. It rested on an irregular deposit of clay and sand.

This fifth bench is continuous along the river hills from the State line to the mouth of George's creek, except where cut away by streams, but sometimes it is so defaced by erosion as to be recognized only with difficulty. It is handsomely preserved at Greensboro', on the west side of the river opposite New Geneva, where it shows vast numbers of rolled stones. Mingled clay and sand occur above it to 300 feet above water-level.

Between George's Creek and Redstone Creek. Below Greensboro' on the river hill, benches occur at 20, 180, 265 and 310 feet above low water. At the mouth of Whitely creek, in Greene county, the third bench of the Stewartstown series, at 180 feet, is very distinct up the creek to the village of Mapletown, and polished fragments are numerous all the way. At the mouth of Muddy creek, in the same county, the fifth bench, covered with rolled and polished stones, is handsomely shown, and along the creek it is quite perfect as far as Carmichaels, where the detrital coating is as thick as it is along the river.

On Pumpkin run, in the same county, this bench is shown with the same features. The measurement given in the Greene and Washington report* is erroneous and the bench is confounded there with one which was not seen in the Stewartstown series, but which seems to be intermediate between the fifth and the sixth, and to be persistent along several of the streams in Greene county at 30 feet above the fifth bench. At the mouth of Ten-mile creek the first, third and fifth of the Stewartstown series are shown, together with the supplemental one just mentioned; while at Frederick, in Washington county, or rather, at two miles back from the river, and near Frederick, is a still higher one, which is clearly the same with the eighth of the Stewartstown series, though the erroneous measurement given in the Greene and Washington county report would make it intermediate between that and the seventh.

* During part of the season of 1875 I used a barometer which proved to be quite bad. In this way came the erroneous measurements referred to.

Between Redstone Creek and Pittsburgh. The benches are handsomely shown on both sides of the river below the mouth of Redstone creek, which enters the river at Brownsville, 50 miles above Pittsburgh. At Belvernon, near the northern line of Fayette county, the deposit on the third bench has been opened to procure glass-sand; and at present two excavations are worked on the opposite side of the river. At the upper one of these the following detailed section was obtained:

1. Alternations of fireclay, gravel and coarse sand, with fragments of varying size; the whole containing much carbonaceous matter in streaks, mostly broken coal; very ferruginous toward the base 12 to 16 ft.
2. Sand, fine and angular, excellent for manufacture of fine window and mirror glass; containing thin, irregular layers of blue plastic clay, with occasional layers of conglomerate cemented by oxide of iron; contains also numerous rounded fragments of rock, some of them very large; the pebbles are of limestone, sandstone, and carboniferous conglomerate.... 16 to 22 ft.
3. Coarse sand and gravel, with many small rounded fragments; much carbonaceous matter, coal, and imperfect lignite; occasionally yields large fragments of trees. This is often a ferruginous conglomerate..... 2 ft.
4. Ferruginous sand, frequently conglomerate; contains some transported fragments of considerable size 2 to 4 ft.
5. Blue plastic clay 0 to 4 ft.
6. Blue laminated shale of the lower barren series.

The plastic clay, No. 5, is evidently derived from the underlying shale on which the deposit rests. The section shown in the other excavation is:

1. Clay, containing rounded fragments, lumps of coal, etc. 10 ft.
2. Dark sand used for moulding..... 7 ft.
3. White sand, used in making glass..... 7 ft.
4. Sandy and clayey material, containing rounded fragments and lumps of iron ore 1 ft.
5. Dark sand 4 ft.

As these excavations are barely half a mile apart, they show the extreme irregularity of the deposit, which is from 40 to 45 feet thick at the upper excavation, while at the lower one it rarely exceeds 35 feet.

At Monongahela city, the third and fifth of the Stewartstown benches are at 190 and 320 feet above low water mark; above these are the sixth and eighth at 1110 and 1190 feet above tide. Between the third and fifth there is an ill-defined bench at 290 feet above low water, which is distinct further down the stream, for a terrace, holding that place, is reported from Peter's creek and Thompson's run. The third bench, also, is well defined down the river, being that along which the Pennsylvania Railroad runs from just below Braddockfield almost to Pittsburgh.

The lowest bench at Monongahela city is at 40 feet above the river or at 750 feet above tide. The Baltimore and Ohio Railroad runs along this

bench for a considerable part of the way below the mouth of the Youghiogheny river. It is the bench along the river front at Pittsburgh.

Benches along George's Creek. The third and fifth benches of the Stewartstown series are persistent along this creek, but constantly rise up-stream so that at the village of Smithfield the fifth is 304 and the third 200 feet above the river at the mouth of the creek. The rise is quite regular and in this distance the lower one has gained five feet on the upper one.

The eighth bench is shown on the south side of the creek near the village of Morris Cross-roads, forming the crests of several flat-topped hills on the divide between George's creek and Grassy run, the latter a tributary to Cheat river. Its absolute level is unchanged, being 1195 feet above mean tide. The sixth bench is found near Grassy run, and the second is there at 80 feet above the run, or 125 feet above Cheat river at its mouth.

Crossing the divide between Grassy run and Rubbler's run, also tributary to Cheat river, several benches were seen, but their relations could not be made out owing to lack of time. On Mitchell's hill, projecting from Chestnut Ridge almost immediately behind the old Springhill furnace, the eighth bench stands out from the mountain for almost 400 yards. This bench is continuous thence southward to the line of West Virginia, where, as the divide between Rubbler's run and Cheat river, it extends for a long distance eastward and westward. Its elevation was determined on this divide and differs from that near Stewartstown by barely five feet.

Returning to George's creek and taking the road from Smithfield to Uniontown, which follows the west side of the valley, one finds the third, fifth and sixth benches constantly persistent along the side of Brush ridge, which, as already mentioned, is the elevated land marking the course of the Saltsburg anticlinal. East from the road are some minor benches whose relations were not made out.

Beyond the creek, on the flank of the mountain, fragments of the eighth bench are occasionally shown, and the same bench is reached on the road at the summit of the divide between George's and Redstone creeks at one mile from Uniontown.

Meanwhile, in ascending the creek, the fifth bench has shown a constant increase in altitude, so that as the divide is approached, that bench takes place of the sixth and finally is merged into the seventh. According to the barometer, the eighth bench is somewhat higher here than at the mouth of Cheat river, being 1206 feet instead of 1195, but the measurement was not verified. No opportunity was afforded for following out the minor benches in this valley, but their steady rise from the river to the village of Smithfield justifies the belief that they rise with the stream until, at last, the "bottom" becomes merged into the highest bench at the head of the stream.

Benches on Redstone Creek. No little difficulty was experienced in the attempt to trace out the benches along Redstone creek, which enters the Monongahela at Brownsville, 50 miles above Pittsburgh. From the river to Upper Middletown, 3 miles below Uniontown, the creek is hemmed in

by high hills and the valley is so narrow in many places that the benches are necessarily very indistinct. It is sufficiently clear, however, that the bench, on which Uniontown is built, is the same with the third of the Stewartstown series as exposed at Brownsville. The transported fragments were seen on Redstone at five or six miles from the river, where the bench is fairly well defined. Further up, the same bench is imperfectly shown at Upper Middletown.

Along the road leading from Uniontown to Connellsville, the eighth bench is reached very soon after leaving the National road, and it is exposed again near Lemont furnace at four miles from Uniontown, where the sixth bench is handsomely preserved at 90 feet below it. The latter bench shows changes in level as insignificant as those of the former.

The eighth bench is persistent throughout the whole of the Redstone valley east from Brush Ridge, but it becomes a little obscure near the summit dividing the waters of Redstone from those of Dunbar creek. There a higher bench was seen, which belongs between the ninth and tenth of the Stewartstown column.

On the old Pittsburgh road leading north from Uniontown, the eighth bench is well shown, and, at the first summit, the tenth bench is reached. This seems to be the most extensive plain along the east side of Brush Ridge.

BENCHES ALONG THE NATIONAL ROAD.

Between Uniontown and the Monongahela River. The National road between Uniontown in Fayette county and Washington in Washington county seems to have been laid out with the view of crossing the summit of every high hill between the two boroughs. It affords excellent opportunity for the study of the higher benches with the least possible expenditure of labor.

The eighth bench is soon reached west from Uniontown, and a persistent floor representing the seventh bench is shown at 50 feet below it. The tenth bench is seen at three miles west from Uniontown; and a rude survey of the surrounding country, made with the level, shows that bench to be very widely persistent and to be the important plain of Brush Ridge.

The ninth bench is reached on the hill holding the eastern outcrop of the *Pittsburgh coal bed* at five miles west from Uniontown. At that place one comes to the benches of Dunlop's creek, and the ninth bench is seen to be constantly distinct along that stream during its passage through the arch of the Saltsburg axis.

On the hill beyond the old hotel at nearly nine miles west from Uniontown, a higher bench is reached, which is shown in several hills in the vicinity, all of them flat-topped. These truncated cones mark an eleventh bench, whose altitude is 60 feet greater than that of the tenth, or 1350 feet above mean tide.

The tenth bench is reached again at a little way further west, and thence for a considerable distance the road runs on the ninth which is handsomely defined.

Thence to within a mile of Brownsville, the country is so disfigured by erosion that nothing can be determined ; but at that distance from Brownsville one comes within sight of the Monongahela river and the road soon falls to the eighth bench, which has an absolute altitude of 1185 feet, if the engineers' station at West Brownsville was correctly identified. This is ten feet less than at the mouth of Cheat river and 5 feet less than on the Connellsville road near Uniontown. The other benches below this are sufficiently distinct along the river above Brownsville.

Between the Monongahela River and Washington. On the west side of the river, the eighth bench is reached within a mile and it is the important one north and south as far as the eye can reach, until one comes to a station, known as Kreppsville, say three miles west from the river as measured along the road. But there, at a short distance north from the road, a higher bench is seen at 1225 feet, which seems to be the ninth of the series and is persistent northward. The road reaches this bench at a little way further west and follows it to near the village of Centreville, where, while crossing a stream, it comes down to the eighth bench. At Centreville, it returns to the ninth, while both north and south from the village a higher bench is seen in fragments, with an elevation of 1245 feet. Still further north, the tenth bench is shown in the crowns of several flat-topped hills, which have an elevation of 1285 feet.

Between Centreville and a mile and a half east from the village of Beallsville, the road runs alternately on the 1225 and the 1245 feet bench, but at the latter place it falls to the eighth as it crosses the valley of a stream emptying into the Monongahela river. It quickly rises again to 1225 and then to 1245 feet, both distinct benches, and within a short distance it comes up to the tenth. The last is the great bench north and south, and apparently it is the most important bench thus far on this side of the river.

West from Beallsville is a high hill, which seems to mark the dividing line between the benches of the Monongahela Valley and those belonging to the valley of Chartiers creek and the Ohio river at the west, though it is broken by Pike run at a little way north from the National road. On this hill, one rises to 1420 and 1445 feet above tide, two splendid benches, and the summit of the hill is little less than 1500 feet.

Descending the west side of this hill, one comes to the 1420 feet bench and goes below it ; but in ascending the first summit east from Hillsborough, he crosses benches at 1420, 1445 and 1475 feet, all of them perfectly distinct, the first two quite as much so as on the east side of the Beallsville Ridge. Descending from this, one soon comes to the tenth bench at 1295 feet, but in ascending to Hillsborough he again crosses benches at 1420, 1445 and 1475 feet and reaches 1505 feet at the hill-top, the three benches being very distinct. Hillsborough is at 12 miles east from Washington.

At eleven miles east from Washington, the road crosses the 1445 feet bench ; at ten miles, the bench at 1380 feet ; and at $9\frac{1}{2}$ miles, the tenth at 1295 feet. At nine miles, one reaches the head of Pike run, and in the

whole region north from the National road, the tenth bench is the most widespread, the one which gives character to the country. At 8 miles and a half from Washington, the general elevation of the country increases and the road rises, so that from that point to the four-mile post the road oscillates between the 1420 and the 1445 feet bench. But near that post it falls to 1375 or 1380 feet and comes upon a fine terrace, which is of considerable extent north and south from the pike.

Between the second and third mile-posts, the road crosses an island of the 1420 feet bench and at the second post it is again at 1375 feet. This is the principal bench of the Chartiers Valley, being well shown on both sides. The lower benches came out in their order from this horizon down to the railroad depot at Washington, which is near the place of the sixth bench.

The observations from the river to Washington were made altogether with the barometer, but under very favorable circumstances, for on repetition the measurements showed insignificant variations; and in both cases the total change in the barometer during the passage was barely five one-thousandths of an inch; the altitudes of the stations terminating the line having been well determined by railroad levels.

BENCHES ON WEST SIDE OF CHESTNUT RIDGE SOUTH FROM THE YOUGHIOGHENY RIVER.

This slope shows for the most part a very regular face in the Redstone region. Near the West Virginia line and beyond that southward as far as the observations were carried, the rocks of the Lower Barren and Lower Productive Coal Series have so far escaped erosion, that the benches below the eighth are easily recognized. Northward from the middle of George's township, in Fayette county, to the divide between Redstone and Dunbar creeks, the lower rocks of the Coal Measures have been in great part removed, and the massive Pottsville (Seral) conglomerate, resisting erosion, has remained to give the mountain its present slope. The benches do not exist where this rock forms the face of the ridge and traces of them are very rare. It is noteworthy that the outcrop of this conglomerate, though at a considerable distance from the plane of the axis, is not much below the average elevation of the summit of the ridge.

On the summit, at the National road, the surface is covered by a fine reddish sand, almost free from clay, which is well shown at the Summit hotel. The well on the opposite side of the road was dugged in this sand to the depth of 40 feet, and the people in the vicinity were surprised by the occurrence of river snails and mussels, many of them being quite fresh looking. This point is about 2400 feet above tide. A well marked bench was seen on the Senton road, 180 feet higher, which extends along that road for nearly two miles south from the National road and is covered with loose sand derived from the disintegration of the Pocono (Vespertine) sandstone. A level bench covered by loose sand can be followed for several miles along the crest of this ridge.

Some of the low gaps, which extend to but a short distance below the summit are beautifully terraced. The benches in Wymp's gap, exposed by removal of the timber, are distinct to one standing even on the opposite side of George's Creek Valley. The gorges made by the larger streams are usually so narrow and have so abrupt walls that no benches remain, and it is doubtful if benches could have existed in any but very few of them. For this reason no benches below the eighth have been fully recognized along the greater part of this face, south from the Youghiogheny river.

BENCHES ALONG THE YOUGHIOGHENY RIVER.

The river "bottom" at M'Keesport is at 765 feet above tide. Thence it is continuous to Connellsville, at the mouth of the Chestnut Ridge gap, where it is 894 feet above tide.

At Perryopolis, just south from the river, a fine bench is shown covered by sand, which contains many enormous boulders, all of which have been brought down from the mountain gaps.

Possum run enters the river almost opposite Connellsville. On the road leading along this run from that borough to Brownsville, a bench, reached at the first summit, barely 200 feet above the river, is the highest limit of transported fragments. All of the boulders are of huge size and many of them weigh not less than a ton. They have polished surfaces and are so numerous that the farmers use them in building fences. This bench is the same with that seen at Perryopolis.

This bench is persistent along the river above Connellsville, but it can be followed only with difficulty as slides in the gaps have masked it at several localities. It is very nearly 200 feet above the river at Connellsville, but thence it rises less rapidly than the river bed, so that at Ohio-pyle Falls it is not quite 140 feet above the stream. While flowing on this bench as its bed, the river ran directly across the neck of the peninsula at Ohio-pyle Falls, and the gorge through which the stream now flows has been eroded since the bed fell below that bench.

At Confluence, immediately above the east end of the gap through Laurel Ridge, the river "bottom," which is only 765 feet at M'Keesport, is 1346 feet above tide or 581 feet higher than the same bench at the mouth of the river. A very fine bench was seen southwest from Confluence at 1820 feet above tide. The persistent bench to which reference has been made, is still seen along the river, but is much nearer the stream than it is at Ohio-pyle. Riding up Castleman's river, which unites here with the Youghiogheny, one soon rises above this bench or rather finds the river bottom merged into it.

BENCHES IN WESTMORELAND COUNTY WEST FROM CHESTNUT RIDGE.

Few available measurements were obtained in this part of Westmoreland county. The survey was made during the autumn of 1876, a season strangely marked by violent fluctuations of the barometer; but no measurements have been accepted as trustworthy except such as were verified by direct comparison with a spirit-leveled line as a base.

Though the observations thus available are very few, yet they suffice to show that the system of benches in this county is the same with that found in Fayette and Washington.

The eighth bench of the Stewartstown series is shown half a mile west from Jacksonville, near the county line on the Pittsburgh and Bedford road, at 1190 feet above tide; a still higher one at Jacksonville with an elevation of 1230 feet, is evidently the ninth of that series. These benches are well shown both north and south from the pike, forming the crowns of many hills, while the tenth is distinct north from the Pennsylvania Railroad. Following the pike one finds the twelfth bench at three miles and a half west from Greensburg, with an elevation of 1380 feet, precisely the same as on the National road many miles southwest; and at two miles west from Greensburg the ninth (?) is shown with an elevation of 1242 feet. Benches were seen north from Greensburg at 1185, 1270, and 1300 feet on the road to New Salem, evidently representing the eight and tenth with the intermediate bench seen in Fayette county between the ninth and tenth.

The highest point at the village of New Salem is on the eleventh bench, which is of wide extent in that part of the country. The benches are finely shown west from New Salem along Turtle Creek and its tributaries, but unfortunately, all of the measurements made in that vicinity proved altogether worthless, owing to flagrant variations in the barometer.

Measurements made on the Bedford pike near Iatrobe, as it descends to Loyalhanna creek, showed the fifth, sixth, eighth and ninth benches at 1050, 1105, 1185 and 1240 feet above tide. The fifth is here the "bottom" of the Loyalhanna. The highest plain seen near the pike is about 1450 feet above tide.

BENCHES IN THE LIGONIER VALLEY.

On the National Road. There was no means of verifying the measurements made here. The base used is the altitude of Chestnut Ridge summit as determined by the original survey at 2400 feet above tide. This determination agrees closely with that shown by the barometer, the railroad level at Uniontown being taken as the base; but as gross errors were made by the engineers in running the line for the road, and as there is no well-fixed point nearer than Uniontown, the altitudes of the benches cannot be regarded as fairly determined. At the same time it may be best to record the levels obtained, because they show that the surface of Ligonier Valley is marked by horizontal benches precisely similar to those seen on the west side of Chestnut Ridge. The following series was made out between the summit and the village of Farmington, midway between Chestnut and Laurel Ridges: 2155, 2060, 1965, 1880 feet above tide. The crowns of the hills in this part of the valley are almost absolutely level and the escarpments of the benches are very steep. The forms stand out more fairly than they do west from Chestnut Ridge.

South from the National road, Laurel Ridge loses its mountain character

and, as it were, breaks down into a broad level country, known as the "Glades," which stretches over into West Virginia and Maryland. Though thus breaking down, the ridge loses little of its height, and the "Glades" are not far from 2200 feet above tide. In general character this plain is precisely like the benches.

A fine series of benches was seen near Indian creek at Springfield in Fayette county, but no way existed whereby the exact altitude could be determined, and no measurements were made.

Near the Loyalhanna. Between Ligonier and the village of Stahlstown in Westmoreland county, on the divide between Four-mile run and the Loyalhanna, the following benches were found: 1690, 1570, 1520, 1480, 1390 and 1245 feet above tide. These measurements were verified by reference to the levels of the Ligonier and Latrobe Railroad at Ligonier. The last three are remarkably near three seen on the National road not far from Hillsborough, and the last two undoubtedly represent the ninth (?) and twelfth of the series.

BENCHES IN SOMERSET COUNTY.

The elevation of Meyersdale on the Pittsburgh and Connellsville Railroad has been well established at 2063 feet above tide. Within sight of that village are three fully defined benches at 2123, 2288 and 2323 feet above tide, as determined by barometer from Meyersdale.

The first bench is the floor of the country away from the Castleman's river; is shown on the hill between Elk Lick creek and the Castleman's; is the first bench on the road to Berlin north from the River, where it is beautifully distinct; and is again reached on the summit beyond the crossing of Blue Lick by that road. At each of these places the bench is seen to be persistent over a wide area.

The second bench is at the hill-top on the property of the Cumberland and Elk Lick coal company, and its place southward from that locality is shown by flat-topped hills. The same bench was seen on the road to Berlin.

The third bench was seen on the road to Berlin at the Pine Hill church as well as at Berlin, where its existence is proved by the flat-topped hills. All of the benches are distinct at Berlin, and the second and third are well preserved along the west face of the Alleghanies.

EAST FROM THE ALLEGHANIES.

The observations here are not in detail. For the most part they were taken hastily along Wills creek and in the vicinity of Cumberland. Enough, however, was ascertained to show that a series of benches similar to that already described, exists along the east side of the Alleghanies in Maryland.

Fine river terraces were seen along the Potomac and on Wills creek, which enters the Potomac river at Cumberland. The chief terrace of the Potomac is easily traced from Cumberland to Piedmont, and has even more rapid rise than along the Youghiogheny or the Castleman's river. The

detrital fragments become very coarse in the mountain region, just as they do on the Youghiogheny and Castleman's, and the deposit bears some resemblance to glacial debris. The huge fragments have been transported but a short distance, and slides from the mountains are mingled with detritus moved by the stream; so that, upon the whole, the deposit has little likeness to the material covering the terraces on the lower Monongahela or Youghiogheny, where the larger blocks have been rounded during their long journey, while many of the smaller ones have been reduced to fine sand or clay.

II.

RESUME OF THE FACTS AND THEIR RELATIONS.

Looking now at the observations recorded in the foregoing part of this paper, we see that although very fragmentary, they show the existence of two sets of benches, in one of which, the higher, the individuals have an almost unvarying level, whereas in the other or lower set, the members have no definite altitude with respect to tide, but vary much, as do the beds of the streams along which they are found. Arranged in tabular form, we have, first the benches of the higher series:

1. Chestnut Ridge, Seaton road.....	above tide, 2580 feet.
2. Chestnut " National road.....	" 2400 "
3. Top bench in Somerset county.....	" 2323 "
4. Middle bench of "	" 2288 "
5. Bottom " "	" 2123 "
6. Bench near Confluence	" 1820 "
7. Sixth bench near Loyalhanna.....	" 1690 "
8. Fifth bench " "	" 1570 "
9. Fourth " " "	" 1520 "
10. Third " " " also at Hillsborough and Beallsville.....	" 1475 "
11. National road, Washington county..	" 1445 "
12. " " "	" 1420 "
13. Second Loyalhanna bench, also Na- tional road near Beallsville and Hillsborough.....	" 1380 "
14. National road east from Brownsville	" 1350 "
15. Tenth bench of Stewartstown series,	" 1290 "
16. Intermediate bench, Dunbar cr., Possum cr., Greensburg.....	" 1270 "
17. Ninth bench of Stewartstown series First Loyalhanna bench...above tide,	1225 to 1240 "
18. Eighth bench of Stewartstown series, above tide,	1195 "
19. Seventh " " "	" 1130 "
20. Sixth " " "	" 1100 "

The elevation of low water at Pittsburgh, as used by the City Surveyor's office, is 699 feet above mean tide.

Comparison of the levels given in this table with those given in the preceding notes shows some discrepancies. The altitudes used in the tables approach the means, or nearly so, of the measurements. At the same time, no bench, aside from No. 17, shows any material variation, and in that two are confounded. That two distinct benches belong here will be seen at once by examination of the notes on the National road and on Westmoreland county west from Chestnut Ridge. But it would be unwise to correct the error in this table, as the numbers there given have been published elsewhere,* and any change in the order might prove inconvenient.

The benches seen in the southern part of the Ligonier Valley are omitted, because their elevation cannot be regarded as satisfactorily determined.

The variations in level exhibited by individual benches of this series are so slight that they may be due either to petty variations of the barometer or to errors in reading it, or to the fact that, in every case, the highest point on the bench was sought, so as to determine the top of the detrital deposit. As that deposit, though very thin, has suffered more or less from erosion, one could not, even with perfect instruments, obtain a series of measurements which would tally accurately. The extreme of variation, even in No. 17 where two benches are confounded, is scarcely 18 feet; so that one is fairly justified in regarding the benches as practically horizontal and parallel.

The deposit on these benches sometimes contains a little clay, but sand greatly predominates. No rolled or polished fragments of stone occur; and such fragments as are present belong altogether to rocks found in the immediate vicinity. Nothing shows that running water had ever passed over these plains, so that if the water were in motion, its effects must have been confined within a limited space.

The benches of the lower series have no fixed level, but are precisely analogous to the bottoms of the streams which flow below them. In tabular form this series may be given as follows:

1. Fifth bench of Stewartstown series....	above tide	1050 feet.
2. Fourth bench of same.....	"	980 "
3. Third bench of same.....	"	950 "
4. Second bench of same.....	"	850 "
5. First bench of same.....	"	790 "

The elevations given in this list are those observed at the mouth of Cheat river, and are used only to show the intervals between the benches at a locality where the series is well exhibited.

It has been said that no absolute altitudes can be assigned to members of this series; the lowest bench is 790 feet above tide at the mouth of Cheat river, but at Pittsburgh it is only 765 feet; the third bench is 950 at the mouth of Cheat, but 920 at the mouth of Turtle creek in Allegheny county. More marked variations occur on George's creek, the Youghiogheny and many other streams.

* *American Journal of Science* for May, 1878; and Part II of Report on the Fayette and Westmoreland District of Pennsylvania (1877).

As mentioned in my first report on the geology of southwestern Pennsylvania (that for 1875), these lower benches are merely shelves cut out of the rock, on which are spread thin deposits of irregularly or even wholly unstratified *débris*. At some localities, the lower part shows little aside from clay, while the upper part is made up almost wholly of sand, but ordinarily one of these occurs in pots within the other.

Transported fragments, rounded or polished, appear with this series. Those in the Monongahela benches have been brought from the south and east, for no rocks are represented except such as occur in the mountains crossed by the Youghiogheny and Monongahela or their tributaries; and no material belonging to the northern drift was found anywhere south from the junction of the Ohio and Monongahela rivers. The detrital covering seems to be greatest on the third and fifth benches, where it is of no small economical importance, the third yielding the glass-sand of Belvernon, and the fifth, the glass-sand of Perryopolis and the fire-clay of New Geneva.

The upper limit of rolled stones shows some perplexing variations, which can be accounted for only by supposing that the higher benches of the series have been worn away from one side of the stream, or that, during the formation of two successive terraces, the channel-way held close to one side. On Cheat river, near Ice's ferry, at nine miles from the Monongahela, the upper limit on the south side is the third bench; near the Line ferry, further down on the same river, no fragments occur on the north side above the fourth, though they are numerous on the south side up to the fifth; the fourth terrace is the upper limit on the south side at Point Marion, whereas fragments are abundant up to the fifth on the north side. No fragments have been found anywhere above the fifth bench.

After passing the third bench, the Monongahela river seems to have suffered changes in its channel way. Below Belvernon, there is distinct evidence that it now flows along a line very different from that followed when its bed was on the third bench. The change was more serious near Pittsburgh. The river had a direct course from Braddockfield to the Allegheny and that line is now followed by the Pennsylvania Railroad. The present channel-way of the river is very tortuous. A similar change is shown at Ohioptyle Falls on the Youghiogheny, where the old channel on the fifth bench crossed the neck of a peninsula, while the new channel-way makes a long and close bend around the peninsula.

The conditions, then, are these: The area in which observations were made covers more than 10,000 square miles; embraces that part of Pennsylvania lying south from the Ohio and Conemaugh rivers and west from the Alleghenies; includes part of Maryland and West Virginia, lying on both sides of the Alleghenies of Virginia; and has the channel-ways of four great rivers, the Monongahela, Cheat, Youghiogheny and Potomac, lying partly within it. Along all these streams are terraces, covered by detritus, which contains many transported fragments polished by running water;

these terraces fall down stream, though not so rapidly as do the present stream beds.

But a second series of benches or terraces appears throughout this whole region and seems to be characteristic of a very much wider area than that in which observations were made. The members of this upper series differ in many respects from those of the lower series; their coating of *débris* contains little clay and no polished fragments; they are almost absolutely horizontal and parallel; they do not merge into the lower series, though as the higher benches often form divides between the streams, the lower or stream terraces always end up in one of them. These horizontal benches begin within the area west from the Alleghanies at 1100 feet above tide; they line the faces of the mountains, they curve round the conical hills and often they are indicated only by the leveled crowns of the higher knobs.

Let us look at these series separately, beginning with higher one.

THE HORIZONTAL BENCHES.

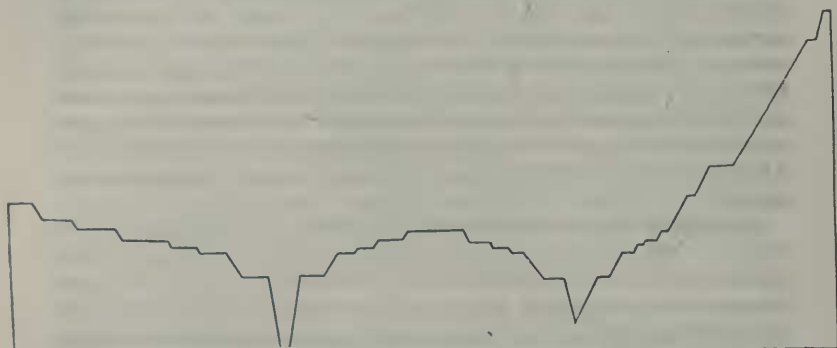
Standing on the highest point crossed by the National road between Chestnut Ridge and the Monongahela river, one finds himself on an island of bench 14, or 1350 feet above mean tide.* Below him an almost continuous plain of the fifteenth bench stretches for a long distance north and south and is broken only by gaps through which the larger streams cross Brush Ridge. He sees also that this plain is the divide between two valleys, one at the east between Brush and Chestnut Ridges, and the other at the west, through which the Monongahela river flows. The latter is uninterrupted, but the former is crossed by strips of the fifteenth bench as well as by lower benches of the series, which breaks its continuity and convert it into a succession of basins. On each side the surface from the summit of Brush Ridge falls off in regular steps.

If now the observer turn his attention to the region lying west from the Monongahela river he will see that the fifteenth bench is a broad continuous plain beyond that river; but that still further back toward the west, the fourteenth, on an island of which he is standing, forms a similar plain, while still further west, the thirteenth, with an altitude of 1380 feet, stretches northward and southward, and is broken only by narrow valleys, in which the larger streams flow.

Should the observer's position be changed to Hillsborough, on the National road nearly midway between the Monongahela river and the borough of Washington, where the elevation is about 1500 feet above tide, he will see that this thirteenth bench is of great extent north and south, while back of it the country rises to a still higher level, again and again, until it reaches to 1445 feet above tide. This last bench is the ridge, which practically separates the benches of the Monongahela from those of the Chartiers Valley further west, though near the National road that ridge is broken by Pike run, along which all the lower benches of the series are shown. From the river westward to Hillsborough, or rather to the ridge passing nearly three

* The numbers are those on the last table.

miles from that place, the surface rises in a succession of steps which are beautifully marked. From the hill-top at Beallsville, three miles east from Hillsborough, the descent of these to the river is well seen. There is here, then, a repetition of the conditions shown east from the Monongahela. The diagram rudely represents the succession.



Profile of benches from Chestnut Ridge to Hillsborough.

In the valley between Brush Ridge and Chestnut Ridge, benches lower than the fifteenth fringe the several drainage areas, while the sixteenth and eighteenth form subordinate divides.

Two general questions present themselves here, the one relating to the time when the valleys were scooped out, the other to the age and origin of these benches by which the sides of the valleys are marked.

Erosion of the Valleys. The present drainage system was outlined at a very early date, in part no doubt before the elevation of any of the great axes; the Conemaugh river taking its rise on the western slope of the Alleghany Mountains of Pennsylvania, breaks through both Laurel and Chestnut Ridges, as well as the Blairsville, Saltsburg and Waynesburg axes, which are west from Chestnut Ridge; Loyallhanna, Jacob's and Dunbar creeks cut through Chestnut Ridge; the Youghiogheny has worn its way across all the main axes west from the Alleghanies of Pennsylvania; Cheat river heads against the Alleghanies of Virginia, and its deep channel-way passes by deep gaps through the Alleghanies of Pennsylvania and all other axes at the west, until it enters that of the Monongahela midway in the Saltsburg arch; while the main fork of the Monongahela river splits the Tygart's Valley axis in West Virginia, flowing for miles in a broad anticlinal valley, and after breaking through the west slope of that axis, runs rudely northwest and north, until, having cut through every axis to the Brady's Bend, it joins the Alleghany river at Pittsburgh.

It seems altogether probable that this system developed itself gradually as the land increased toward the central part of the basin, and that the great streams flowed very near their present lines before any marked elevation of the axes had taken place.

One is not fairly justified by the facts in supposing that the system was established after the axes had been elevated enough to affect the topography. Several canoe-shaped synclinals lie between the Alleghanies of Pennsylvania and Laurel Ridge; a similar synclinal exists between Laurel and Chestnut Ridges and another between Chestnut and Brush Ridges. A drainage system, like that now existing, could hardly have originated in parallel synclinal troughs separated by distinct ridges such as these mountains are. A series of lakes might have been formed, but that they would have been in communication so as to give a uniform drainage system, tending wholly westward and breaking through the axes, seems not altogether probable; for Laurel and Chestnut Ridges are little, if at all inferior to the Alleghanies of Pennsylvania, either in altitude or in the inclination of the strata.

It is equally difficult to believe that the streams now flow along lines of original weakness, crossing the several axes, or that their present courses through the mountains mark lines of transverse fracture. A transverse fracture would necessarily be parallel to the direction of the disturbing force, and it could arise only in case the rock on one side of a line has greater power of resistance than it has on the other. Associated with the transverse fracture there would be a greater or less faulting of the axis. So that there would be no difficulty in deciding the presence or absence of such a fracture; for even were the direct evidence masked by river erosion, the side throw would be distinct. But there are no evidences of such side-throws near the gaps or anywhere else in these mountains, and all the conditions go to show that any supposition of their existence is altogether improbable. For, as I have shown elsewhere,* though the axes are thrown off successively toward the southeast, yet there are no breaks. The two parts of a shifted axis overlap, one becoming gentle toward the north and the other toward the south, until each is over-ridden by the other.

In addition, such a hypothesis necessarily assumes not only that these fractures must have existed in all of the mountain axes, but also that much more extensive erosion had taken place in the region west from Chestnut Ridge than any of the more eastern troughs, in order that by deepening the fractures in the several mountain ranges, the waters could be drawn off into the next trough west.

While neither the hypothesis nor its attendant assumption goes beyond the range of possibility, each oversteps very far the bounds of probability. Erosion must have been going on all the time east from Laurel Ridge, while the valleys were deepening on the west side of Chestnut Ridge; and a system of drainage must have existed in one region just as well as in the other; unless, indeed, the region east from Laurel Ridge was arid, which is wholly improbable. If these systems were not one from a very early date, it is difficult to conceive how they could become one at any later date; at all events it would be impossible by any natural deepening of gaps or removal of divides to divert the drainage from one side of an axis to the

* Reports on Fayette and Westmoreland Dist. of Penn.

other in a region like this, even were the ridge no greater than Brush Ridge, which marks the course of the Saltsburg anticlinal.

The accuracy of this statement will be apparent at once to one standing on the National road at the summit of Chestnut Ridge, where on the west he sees deep gorges made by Redstone creek, while on the east side he may look down into the almost equally deep gorges made by Cheney's run. The water from the former flows to the Monongahela by way of a close gap through Brush Ridge; while that from the latter, flowing against the dip of the rocks, which rise southward towards the point of the Ligonier canoe, passes by way of Sandy creek to the Cheat river. Each stream has a rapid fall, so that no possible cutting down of the divide by natural operations would suffice to divert the drainage from one side to the other.

Altogether the more probable hypothesis, therefore, is that the main streams flowed along or near their present lines before the axes, which they cross, had been elevated so as to affect the topography; and that the gaps were eroded during the slow elevation of the folds. This process has been well described by Mr. Gilbert in his *Memoir on the Geology of the Henry Mountains*, and Maj. Powell has given instances where it is clearly impossible that the disturbance could have ante-dated the erosion. Some of these are analogous to the ones under consideration.

The great length of time which has elapsed since this erosion began is shown not only by the general wasting of the surface between the axes, but also by the structure of the gaps; for in these, above the highest river terrace, the walls slope with comparative gentleness, and in many places they are deeply trenched by streams flowing directly along the axial line; whereas below the line of the highest river terrace, the walls are abrupt. The same conditions exist in minor gorges made by such streams as George's creek, Redstone creek, Jacob's creek and Sewickley creek through the axis of Brush Ridge, for there also the lower part of the gorges has abrupt walls, while the upper part is wide, with walls sloping gently toward the streams. It will be understood, of course, that there are occasional exceptions to this general statement of the conditions.

That the erosion of the valleys ante-dated the formation of the horizontal benches is shown by the distribution of the benches themselves. These appear in many localities only as the crowns of flat-topped hills; the fifteenth is an extensive plain along Brush ridge, but between that and Chestnut Ridge it occurs only in the crowns of hills or as the summit of narrow strips stretching from one ridge to the other. Some benches are seen only along the mountain slopes, while others line both sides of narrow valleys reaching far from the rivers into the interior of the counties. All of the terraces below the twelfth are shown along Pike run in Washington county, though that stream breaks through the ridge which shows the highest benches seen west from Chestnut Ridge. For this reason, one riding from the Monongahela to Washington along the National road frequently descends from higher benches to lower ones and finds them all equally distinct. The lower benches can be seen along the

valleys for a considerable distance from the National road towards the river, and when followed out they are found to be continuous with those previously crossed on the road.

Age and Origin of the Horizontal Benches. The surfaces of these benches are still level, and in many places the escarpments are so nearly perfect that one has difficulty in believing that the flat-topped hills are not ancient fortifications. The detrital covering is well preserved, though it consists only of loose sand with occasionally a little clay.

Some may suppose, that, in measure at least, these benches are creatures of the imagination and that they are merely such as must occur in a region where the rocks are of unequal hardness and are horizontally stratified. But such a supposition would be wholly erroneous. The rocks are not horizontally stratified and the benches bear no relation whatever to the dip of the rocks. Thus in Springhill township of Fayette county, on the west slope of Chestnut Ridge, the rocks dip at from 4 to 6 degrees toward the north-west, but the fifteenth bench is as level there as it is on the side of Brush Ridge, eight miles away, where the dip is but one degree, or at Uniontown, ten miles away, where the dip is three degrees, or at any other locality within the whole region. That no relation exists between the stratification and the benches is a fact which cannot be stated too positively.

It has been suggested that these benches may be regarded as marking base levels of erosion, such as have been described by Maj. Powell. In defining the term, that author uses the following language: "We may consider the level of the ocean sea to be a grand base-level, below which the dry lands cannot be eroded; but we have for local and temporary purposes, other base-levels of erosion, which are the levels of the principal streams which carry away the products of erosion."

As Major Powell states, the term "level" is used with some freedom in reference to stream-beds, and the term base-plane might have been more apt. Major Powell notes the fact, that, for all practical purposes, a stream ceases to deepen its channel-way long before the bed has reached the level of the lower end of the stream. If I understand the doctrine aright, it is, that after the corrasive energy of the stream has reached its minimum, it is less rapid in its effect than the wasting away of the adjoining surface; so that eventually the whole region will be worn down to a slightly inclined plane, having about the same altitude with the base-line of erosion or the bed of the stream.

It is with some hesitation that I venture to disagree with those who would explain the phenomena on this hypothesis, for they have had opportunity for very extended study of surface geology; but the explanation is insufficient here, and is open to serious objections, some of which are almost insuperable.

The wide-spread horizontality of the benches seems to conflict with any such explanation. One can conceive that all the streams feeding the Alle-

ghany and Monongahela could reach the limit of corrasion at the same altitude above tide, and that, after that limit had been reached, the tributaries of those streams could continue to eat away the surface until at length a broad and almost horizontal bottom might be formed on each stream, all having the same elevation. But such a condition is inherently improbable. Aside from that, it would not suffice to explain the phenomena, for the benches would not be horizontal, they would be river terraces, with a gentle slope down stream.

If the plains of south-east Pennsylvania and the adjoining region have resulted from any such process as that described by Major Powell they must be very ancient ; for although the rainfall has always been very great in this region, yet that very excess of rainfall has been the means of preventing too rapid erosion by encouraging the growth of vegetation. In like manner, if the plains had originated as suggested, they would necessarily ante-date the tremendous erosion by which the valleys below have been scooped out ; for often they are shown only by the leveled tops of slender hills ; they must be fragments of once continuous plains, which have been broken up by the erosion producing the valleys as they now exist. It is needful then to thrust back their origin to a time when the drainage was in its infancy.

In this case the origin might seem to be readily explained. It may be said that when the drainage was in its infancy the fall of the streams was insignificant ; that if the drainage existed before the mountains rose, and the corrasive power of the streams was equal to or somewhat greater than the rate at which the axes were elevated, there would be no difficulty in understanding the formation of the benches ; for since the flow was gentle the limit of corrasion would soon be reached and erosion would soon produce the benches, so that at each elevation of the land a new bench would be formed.

But all this appears to be in discord with the facts. The benches could not have been formed during the elevation of the axes, for the rocks were not lifted vertically ; the elevation was effected by a lateral thrust which wrinkled the rocks. It would have wrinkled in like manner, any stratum resting upon them, and the horizontality of the benches would have been destroyed.

The phenomena, too, are too recent ; the deposits are too well preserved. If horizontal plains, such as these, had existed so long ago, those plains would not have been in existence to-day. It is incredible that in a region with great rainfall, perfectly horizontal plains should remain unbroken, while valleys, hundreds of feet deep, were being dugged out below them. As already stated, the deposits on these benches consist only of loose sand with occasionally a little clay. If the benches were of ancient origin this covering would be absent ; the flat crowns of the hills would be rounded, especially where the rock was a soft shale as on Chestnut Ridge and in the Ligonier Valley, where, however, the horizontality is complete and the benches particularly well preserved.

But the character of the deposit on these benches shows that it could not have accumulated under such conditions as must have existed had the plains resulted from lateral corrasions by streams with but slight fall. Under such circumstances, as has well been shown by Maj. Powell, the debris torn away by tributary streams would be distributed over the widened flood-plain of the main stream and would not be washed away by that stream. Such a deposit would contain many transported fragments, fragments, indeed, of rocks belonging not far away, but showing distinct traces of water-wear, for their motion would be slow and their exposure long-continued, owing to the slight fall of the transporting streams. No small period would elapse from the time of tearing them from the rock to that of depositing them on the flood-plain; and during all this period they would be subjected to the action of water.

This condition is well shown on the great plains stretching eastward from the Rocky Mountains for hundreds of miles and finally merging into the prairies of the Missouri-Mississippi Valley. These plains are covered with a deposit which originated certainly according to Maj. Powell's doctrine. The character of the deposit is shown in the channel-ways of all the streams. On top is an irregular layer of fine silt, which rests on a mixed mass of fine silt, gravel and large water-worn fragments; while, above all, over the whole surface, water-worn fragments are freely strewn. The higher benches toward the mountains as well as those on hills far out in the plains show a similar covering. The coarser beds of gravel are often cemented by carbonate of lime into firm conglomerates. But this is not the character of the deposit on the horizontal benches of the region under consideration. As has been said so often in this paper, the deposits on these benches contain no water-worn, transported fragments; the only fragments found belong clearly enough to the underlying rocks, and show no signs of having been subjected to the action of running water.

The doctrine of base-levels of erosion, though adequately and beautifully explaining the conditions existing in the arid regions of the far-west, fails to account for these horizontal benches in the Alleghany region, one of great rainfall. These plains are too widespread, too nearly horizontal and parallel, too recent and too nearly free from traces of running water, to be regarded as marking base lines of erosion referable to stream beds.

It is impossible to account for the phenomena on the hypothesis of a great flood's sweeping down over the whole region, for the action of such a flood would be too violent to produce effects such as have been described in this paper.

The benches bear much resemblance to beach lines, marking successive stages of emergence from a body of water; but they are not due to base-level erosion in the full sense of that term in this connection. The areas of the benches are so insignificant in many places that they could not have been leveled by water falling on and flowing off the surface. Such a process would require a vast length of time, altogether too vast in view of the

freshness of the detrital covering on the highest benches. More than this if the time were long enough to admit of leveling the insignificant areas by ordinary erosion, it was not too short to admit of leveling the larger areas and of removing the mountains during the successive stages. But no such leveling exists; on the contrary the mountains and hills still exist, and the numerous benches are found on their sides.

Had the phenomena been observed only on the west side of the Alleghanies, there might have been room for supposing that the benches resulted from the draining away of some great lake; but this hypothesis would be useless, since one would have difficulty in finding a sufficient barrier at the south or west for the retention of the water. For in those directions the surface falls away so rapidly that in the whole of south-west Pennsylvania and West Virginia, west from the mountains, it rarely rises to even 1500 feet above mean tide. But there are distinct benches at 2400 feet above tide. A temporary barrier, 1000 feet high, is beyond the reach of even the most indolent credulity.

The conditions suggest that these benches were formed by ocean wear between tides. Their horizontality and their excessively comminuted deposits go far toward supporting this supposition. The features closely resemble ancient sea beaches in other parts of the country. Such a supposition involves a submergence to a distance of more than 2500 feet above the present line of mean tide; and the submergence would have to be somewhat greater to account for the even crests of the Alleghanies and other ridges west from the Blue Ridge. Horizontality of crest characterizes all those ridges as far south, at least, as the New river of West Virginia, for there they look, not like mountains as generally understood, but rather like a succession of gigantic waves which have not approached near enough the shore to show signs of breaking.

To some, perhaps, the absence of marine fossils may be regarded as a vital objection to this hypothesis. But not so. The detrital covering is loose, not compact, and the occurrence of fossils would be cause for surprise. Their absence is not.

Immense deposits occur in the Rocky Mountain region which are unquestionably of marine origin, yet over great areas they contain no traces of fossils. The enormous red sandstone seen along the east face of the Rocky Mountains in Colorado, is to all appearance devoid of fossils. Similar conditions exist in the sandstones of the Upper Cretaceous or Lignitic series in by far the greater part of Colorado and New Mexico. They frequently contain fucoids and remains of other plants, but animal remains are absent from the loose rocks. But here and there calcareous or ferruginous materials have rendered the rocks compact, and in such cases animal remains do occur.

Of like character is an instance mentioned to me by Prof. Geikie. A Lower Carboniferous sandstone in Scotland is celebrated as a repository of fossil trees; but though searched diligently at many localities during a whole generation, it failed to yield even a single relic of animal life until

November of 1877, when a Mytiloid shell, which is associated with *Orthoceras* and other forms of marine life elsewhere in the district, was found inside the cast of a *Lepidodendron*, where it had been preserved by the superior hardness of the material in which it was imbedded.

If fossils were ever present in the detritus covering these benches, they have been dissolved out by ordinary water or by water carrying carbonic acid in solution. As the coating is merely incoherent sand, all animal remains would be leached out of it in a comparatively short time, while fragments of wood, which occasionally occur, would be unaffected. Instances of this kind are common enough, so that they need not be referred to in detail.

An objection to the marine origin of these benches may be found in the existence of fresh water forms on the summit of Chestnut Ridge. That such forms do occur there seems to be altogether probable from the testimony of several persons, but I have been wholly unable to discover the localities, although I have made diligent search. The shells obtained at the summit of that ridge near the National road could not have been numerous, for close examination of the sand on several occasions yielded not even a fragment.

If remains of fresh-water mollusks do occur on the crest, they mark places once occupied by ponds such as those now to be seen at a little way north from the National road and very near the summit. The presence of the great Lower Carboniferous limestone is exceedingly favorable to the growth of mollusks. This explanation is the more acceptable because according to the statements made, the specimens are too well preserved to admit of the supposition that they had been entombed for any considerable length of time. They still retain the epidermis. Such being the case their presence has no bearing whatever on the age or origin of these benches.

If these benches are old beach lines, as seems by no means improbable, they show that, at some period since the glacial time, the sea has covered the greater part of the continent, certainly submerging the present summit line of the Alleghanies in Pennsylvania. This would confirm the surmise offered by Dr. Hitchcock in his "Illustrations of Surface Geology," when discussing the sea-beaches found along the streams of New England.

The lowest of these benches is at 1100 feet above tide. This statement ho'ds good only for the extreme north-western part of the area examined. In the Ligonier Valley the lowest horizontal bench is at a greater altitude, so, also, in southern Somerset county. Of necessity the horizontal benches ceased when the drainage was re established, that is when the line of submergence sank below the stream beds previously existing. When the water sank below 1100 feet, it fell below that level in this region and the lower series of terraces began to form; but further west and south-west, where the elevation of the country is less than within the area described, horizontal benches should be found at altitudes less than 1100 feet above tide, possibly down to within a very little way above the tide-level.

THE RIVER TERRACES.

The river terraces fall down stream and are covered by irregularly bedded sand, clay or gravel, containing transported fragments which have been rounded by the action of running water. When followed up the streams these terraces show differences among themselves in degree of slope, so that each is merged successively into the next higher, until that, which at the mouth of the stream is the river "bottom," becomes the only terrace and is lost at last in one of the lower horizontal benches.

For the most part the terraces occur at the same elevation on both sides of the stream, being divided by the channel-way just as the present "bottom" is divided. Sometimes a single terrace and occasionally the whole series of terraces is wanting on one side of the stream. In such a case it is clear enough that erosion was confined to one side so as to remove all traces of the terrace or to prevent the formation of the terraces, just as is seen in the present channel-way, the "bottom" being present often on only one side while stratified rocks reach to the water's edge on the opposite side.

As stated in my report on the Greene and Washington district of Pennsylvania (1875), these terraces are merely shelves in the rock, on which a thin coat of detritus rests. Mr. G. K. Gilbert, in his Memoir on the Geology of the Henry Mountains, describes the occurrence of similar terraces in those mountains.*

These terraces then do not fall in the same category with those described by Dr. Hitchcock in his "Illustrations of Surface Geology," for those had been eroded from valleys previously filled by gravels. No evidence has been found suggesting that any valleys of that sort exist in the region under consideration, while there is good reason for believing that the valleys lined by the river terraces, described in this paper, were not in existence to be filled with gravels.

The terraces below Pittsburgh on the Ohio river are covered by a deposit consisting largely of northern drift brought down by the Alleghany and Beaver rivers. No such material is found along the Monongahela and other rivers south from the Ohio, as they flow altogether beyond the southern limits of the drift. But their age is as clearly shown as is that of the terraces on the Ohio. The fifth terrace, at New Geneva, on the Monongahela, has a layer known as the "Swamp Clay," which contains much half-rotted wood. With the wood are berries like those of the black haw and in the same clay a well-preserved acorn cupule was found. In the same vicinity, as well as near Morgantown in West Virginia, the third terrace shows many *Unio* shells in an advanced stage of decay, while at Belvernon, on the Monongahela, much wood is found on this terrace. That the third terrace is older than the second and that this is older than the river

* This work has not been published at the time of writing, but Mr. Gilbert has very kindly given me a set of plate files for use during the preparation of this paper. It contains an elaborate discussion of the whole subject of land sculpture, embracing the results obtained by Mr. Gilbert during his long study of the Colorado Plateau.

"bottom," is sufficiently proved by the condition of the *Unio* shells on the several terraces. For those on the first are fresher than those on the second, and those on the second are fresher than those on the third ; while the species on all are apparently the same with those now existing in the river.

Since the deposits on the first, second, third and fifth terraces are distinctly of recent origin, there would seem to be good reason for supposing that the valleys below the highest of the terraces are also of recent origin. It has been suggested, however, that the terraces resulted only from re-working of the sides of valleys which had been digged out previously. But this suggestion seems to be hardly in accord with the facts.

It must be remembered that the streams flow on a rock bottom, so that the beds are now at the lowest point ever reached by them ; that there is no evidence thus far, going to show that any gravel deposits ever existed along the Monongahela, so as to make its valley like that of the Ohio at Wheeling or Steubenville ; that the deposits on the terrace shelves are not remains of valley gravels, but simply accumulations of material brought down by the streams and distributed as the matter has been distributed on the present "bottom." Rocky banks are shown at the mouths of tributary streams. Had the valley been filled by gravels, it is incredible that even the most comprehensive erosion could have failed to leave some trace of their existence.

The structure of the valleys below the highest terrace is very different from that observed above it ; for in the upper portion the sides are gently sloping, whereas below the highest terrace they become steep almost at once. Above the line of that terrace, the valleys of the smaller streams are broad swales, with smooth sides, while below that line the streams usually flow in gorges. The abruptness of this transition from gentle to abrupt walls shows that erosion had been long at work on the upper part of the valleys and that it began in the lower part at a comparatively recent period ; in other words, that the lower portion was eroded after the upper portion had acquired its present form.

The river terraces are relics of river beds, such are the present "bottom ;" and the valleys below the line of the highest river terrace have been eroded since the drainage system was re-established by withdrawal of the submerging flood to below the line of the former stream beds.

CONCLUSIONS.

The general conclusions which seem to flow readily from the facts recorded are :

First. That the erosion, to which is due the general configuration of the surface above the line of the highest river terrace, began even before the elevation of the antilinal axes and continued until the region was submerged in post-glacial time.

Second. That the horizontal benches are due to the re-working of pre-existing valleys, and that they mark stages of rest during the emergence of the continent from the submerging flood.

Third. That the river terraces and the valleys, which they line, were formed after the drainage system had been re-established by withdrawal of the water to a level below that at which the streams had previously flowed.

It will be seen that the last conclusion leads to one of wider application.

So long time had elapsed between the beginning of this drainage and the coming of the great flood, that deepening of the water-ways had become not more rapid than the general wasting of the adjacent country ; for we find comparatively gentle slopes down to the line of the highest river terrace. But after the drainage had been re-established, the rate of flow must have been more rapid than before, so as to increase the corrosive power of the streams to far beyond what it had been, for in the newer parts of the valleys the sides are abrupt. There must, therefore, have been a change of altitude with respect to tide-level, to lead to this increased rate of flow and the consequent increased speed with which the channel-ways were deepened.

It would appear then, that, after the submergence following the glacial period, the continent rose to a greater height than it had before the submergence, or that the ocean was drawn off to a lower level than before ; the result in either case being the same—to depress the mouths of the great rivers, to increase the fall of the streams, and therefore to cause the deepening of the channel-ways.

The Philosophy of the Biblical Account of Creation.

By Aug. R. Grote, A. M.

(Read before the American Philosophical Society, September 19, 1879.)

Mr. Grote introduced his subject with a list of works which he had consulted, by the following authors : Keil, Kuenen, Colenso, Bleek, Sharpe, Haverick, Geiger, Goldziher, Geo. Smith, Delitzsch, Cory, H. C. Rawlinson, Geo. Rawlinson, Von Herder, Arnold, Spiegel, Simrock, Max Müller, and Prof. Adolf Duschak.

He then gave in brief the historical distribution of the Shemitic languages and their literary remains ; following this with the Hebrew text (in English letters) of the first two chapters of Genesis, and in opposite columns his own translation, with that of the authorized English version in parenthesis, thus :

20. Vayyomer Elohim Yishr'tzu
hamnayim sheretz nefesh chayyah
v'of y'ofef alba aretz, al p'nay rakee-
ah hashamayim.*

20. And Elohim (God) said : Let
the waters abound with (bring forth
abundantly) creeping (the moving)
creature living (that hath life) and
fowl shall fly (that may fly) above
the earth in the face (in the open)
of the expanse (firmament) of hea-
ven.

* Syntactically the word "v'of" (and fowl) besides being the subject of "y'ofef" (shall fly) may be the object of "Yishr'tzu" (abound with). The common English version gives it exclusively as the object, and supposes a relative pronoun understood.